

REMARKS

Applicant gratefully acknowledges the Examiner's helpful comments offered to Applicant's undersigned counsel during a personal interview conducted on September 10, 2004. Applicant notes that during the interview, Applicant's undersigned representative presented arguments in support of the novelty of claimed invention, and clearly distinguished the claimed invention over the Sayyah reference.

At the personal interview, the Examiner stated that she would again review the Sayyah reference, taking Applicant's arguments into consideration. This Amendment is based on the arguments presented by the undersigned representative at the personal interview.

Claims 19-52 and 119-127 are all the claims presently pending in the application.

Claims 19-52 and 119-127 stand rejected under 35 U.S.C. § 102(b) as being anticipated by Sayyah, et al. (Published in Journal of Crystal growth 77 (1986) pp 424-429). Claims 37-52 and 122-127 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Sayyah, et al. and Admitted Prior Art.

These rejections are respectfully traversed in the following discussion.

I. THE CLAIMED INVENTION

The claimed invention (e.g., as recited in claim 19) is directed to a method for producing a gallium nitride group compound semiconductor by using an organometallic compound vapor phase epitaxy. The inventive method includes setting a mixing ratio of a silicon-containing gas to at least one other raw material gas at a desired value in a range over which a conductivity of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio so as to obtain a desired conductivity (1/resistivity) of the gallium nitride group compound semiconductor, and forming the gallium nitride group compound semiconductor by feeding the silicon-containing gas and the at least one other raw material gas at the mixing ratio.

In another aspect (e.g., as recited in claim 20), the inventive method includes setting a mixing ratio of a silicon-containing gas to at least one other raw material gas at a desired value in a range over which a carrier concentration of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio so as to obtain a desired carrier concentration of the gallium nitride group compound semiconductor, and

forming the gallium nitride group compound semiconductor by feeding the silicon-containing gas and the at least one other raw material gas at the mixing ratio.

Conventional methods do not set a mixing ratio of a silicon-containing gas to at least one other raw material gas during the vapor phase epitaxy at a desired value in a range over which conductivity (e.g., or a carrier concentration) of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio.

The claimed method, on the other hand, includes setting a mixing ratio of a silicon-containing gas to at least one other raw material gas at a desired value in a range over which a conductivity (e.g., carrier concentration) of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio.

The inventive method enables a production of a gas-phase grown GaN layer of high purity. That is, it provides an n-type GaN layer with high resistivity without requiring a doping with impurities, unlike conventional technology which provides n-type GaN with low resistivity when no doping is performed.

III. THE PRIOR ART REFERENCES

A. The Sayyah Reference

The Examiner alleges that Sayyah teaches the invention as recited in claims 19-52 and 119-127. Applicant submits, however, that there are elements of the claimed invention that are not taught or suggested by Sayyah.

Sayyah discloses factors influencing the properties of epitaxial layers of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ grown on sapphire substrates by an atmospheric pressure metallorganic chemical vapor deposition (MOCVD) technique (Sayyah at page 162).

However, Applicant submits that Sayyah does not teach or suggest a method for producing a gallium nitride group compound semiconductor by an organometallic compound vapor phase epitaxy, where the method includes setting a mixing ratio of a silicon-containing gas to at least one other raw material gas at a desired value in a range over which a conductivity (e.g., or a carrier concentration) of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio, as claimed, for example, in claims 19-20.

Clearly, these novel features are not taught or suggested by Sayyah. Indeed, Applicant

would first point out that the Examiner considers that "conductivity = mobility x Si concentration" (e.g., see the Office Action at page 3, lines 13-14). However, this understanding of the Examiner's is incorrect. Instead, the equation must be "conductivity = elementary electric charge x mobility x electron concentration."

Secondly, Applicant notes that the Examiner considers that Si concentration is equal to electron concentration. However, this too is incorrect.

Applicant respectfully notes that when a Group IV element (e.g., Si) is replaced with a Group V element (e.g., N), one electron in the outermost shell is lacking. Accordingly, when this hole is excited to the valence band, ordinarily it will be a p-type semiconductor.

Similarly, when a Group II element (e.g., Mg) is replaced with Ga or Al, an electron in the outermost shell is lacking. Accordingly, when this hole is excited to the valence band, ordinarily it will be a p-type semiconductor.

A gallium nitride compound semiconductor, however, has quite peculiar circumstances compared with other semiconductors.

First, when Mg is doped into a gallium nitride compound semiconductor, the semiconductor cannot become a p-type semiconductor. This is disclosed, for example, in Akasaki (one of the inventors of the present invention) et al.'s document in the *Japanese Journal of Applied Physics*, pp. L2112-L2114, which has been filed as an IDS document in the present Application.

Similarly, when Si is doped to a gallium nitride compound semiconductor, electron concentration decreases (that is, holes tend to be generated) but p-type conductivity with lower resistivity cannot be obtained. Indeed, Tietjen et al. disclose that electron concentration decreases by doping Si as an acceptor impurity in GaN. In short, TietJen et al. show that Si tends to increase generation of holes.

Second, in the conventional art before the present invention was invented, even if a gallium nitride compound semiconductor is not doped with any impurity, it has an electron concentration of 10^{18} to $10^{20}/\text{cm}^3$. Thus, even if Si is doped into this gallium nitride compound semiconductor, electron concentration cannot be controlled linearly. Ordinarily, a semiconductor doped with no impurity has quite a small electric concentration. In speculation, an electron concentration calculated from a band gap energy of a non-doped GaN is $1 \times 10^{-9}/\text{cm}^3$. But actually an electron concentration of a non-doped GaN is 10^{18} to

$10^{20}/\text{cm}^3$.

Accordingly, electron concentration cannot be controlled to increase linearly by controlling Si concentration before the present invention was invented. On the contrary, prior to the present invention, it was understood that Si concentration instead contributes to a decrease in electron concentration.

Accordingly, the equation "Si concentration = electron concentration" had not yet been established in a gallium nitride compound semiconductor before the present invention was invented.

Further, with respect to Sayyah, Sayyah may disclose that Si is a shallow donor. However, Sayyah never measures electron concentration. Indeed, on page 135, line 18 to page 138, line 10, Sayyah discloses as follows:

(1) Conductivity is never changed by doping Si

In other words, even by increasing Si doping concentration, electron concentration never increased, and

(2) Sayyah considers the possibility that this is caused by Si preventing electrons from being exciting into a conduction band.

The Examiner attempts to rely on Figure 32 in Sayyah to support her allegations. However, the Examiner is clearly incorrect.

Indeed, as described above, while Figure 32 shows that Si concentration in a semiconductor increases by increasing flow rate of silane gas in a gallium nitride compound semiconductor, the vertical axis of the graph does not represent electron concentration. Moreover, Figure 32 does not show a linear graph. On the contrary, electron concentration of the present invention increases linearly (e.g., substantially linearly) according to Si concentration.

Sayyah clearly discloses that electron concentration does not increase even when Si concentration increases.

Accordingly, the Examiner's understanding that electron concentration is equal to Si concentration is completely incorrect. Further, the Examiner's assertion that Sayyah shows

electron concentration is proportional to Si concentration in Figure 32, is also completely incorrect.

The Examiner also attempts to rely on page 125 and table 14 in Sayyah to support her position. However, the Examiner is again incorrect.

In fact, on page 125, Sayyah merely teaches that Si has a shallow donor level (Sayyah at page 125, lines 11-14). Further, Table 14 provides incorporation rates of Si (r_{SN}) as a function of silane input flux. However, nowhere on page 125 or in Table 14 (or anywhere else for that matter) does Sayyah teach or suggest setting the mixing ratio of silane to another raw material gas in a range over which a conductivity (e.g., carrier concentration) of the semiconductor increases substantially proportionally with the mixing ratio.

Therefore, Applicant submits that Sayyah does not teach or suggest each and every element of the claimed invention. Therefore, the Examiner is respectfully requested to withdraw this rejection.

B. The Admitted Prior Art (APA)

The Examiner alleges that Sayyah would have been combined with Admitted Prior Art to form the invention of claims 37-52. Applicant submits, however, that these references would not have been combined and even if combined, the alleged combination would not teach or suggest each and every element of the claimed invention.

The APA teaches that an n-type layer of GaN compound semiconductor is grown on a surface of a sapphire substrate or on a buffer layer of AlN (Application at page 1, lines 18-22). However, it is difficult to control the conductivity of the n-type layer of GaN compound semiconductor (Application at page 2, lines 6-14).

Applicant respectfully submits that these references would not have been combined as alleged by the Examiner. Indeed, the APA is unrelated to Sayyah, and no person of ordinary skill in the art would have considered combining these disparate references, absent impermissible hindsight.

In fact, Applicant submits that the Examiner can point to no motivation or suggestion in the references to urge the combination as alleged by the Examiner. Indeed, contrary to the Examiner's allegations, neither of these references teach or suggest their combination.

Therefore, Applicant respectfully submits that one of ordinary skill in the art would

not have been so motivated to combine the references as alleged by the Examiner. Therefore, the Examiner has failed to make a prima facie case of obviousness.

Moreover, neither Sayyah nor the Admitted Prior Art, nor any combination thereof teaches or suggests a method for producing a gallium nitride group compound semiconductor by vapor phase epitaxy, which includes setting a mixing ratio of a silicon-containing gas to at least one other raw material gas in a range over which a conductivity (e.g., or a carrier concentration) of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio, as claimed, for example, in claims 19-20.

Clearly, these novel features are not taught or suggested by the APA. Indeed, Applicant would first point out that the Examiner is not relying on the APA as allegedly teaching these features but instead merely relies on the APA as allegedly teaching growing a GaN based layer on a GaN based buffer layer.

In fact, nowhere does the APA even teach or suggest any relationship between a mixing ratio of a silicon-containing gas to at least one other raw material gas, and a conductivity of a gallium nitride group compound semiconductor, let alone setting such a mixing ratio in a range over which a conductivity (e.g., or a carrier concentration) of the gallium nitride group compound semiconductor increases substantially proportionally with the mixing ratio. Thus, the APA clearly does not make up for the deficiencies of Sayyah.

Therefore, Applicant submits that these references would not have been combined and even if combined, the alleged combination would not teach or suggest each and every element of the claimed invention. Therefore, the Examiner is respectfully requested to withdraw this rejection.

III. FORMAL MATTERS AND CONCLUSION

In view of the foregoing, Applicant submits that claims 19-52 and 119-127 all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.


Serial No. 10/052,347
Docket No. F01-257-UScont

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The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 9/21/04



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